

Bridge Preservation Treatments and Best Practices

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Maintenance is the Treatment for Bridge Preservation

OVERVIEW

- Examine maintenance operations
 - Literature
 - Other States
 - Indiana
- Develop recommended list of maintenance activities
- Evaluate Effectiveness (LCCA + Research)
- Formulate maintenance operations

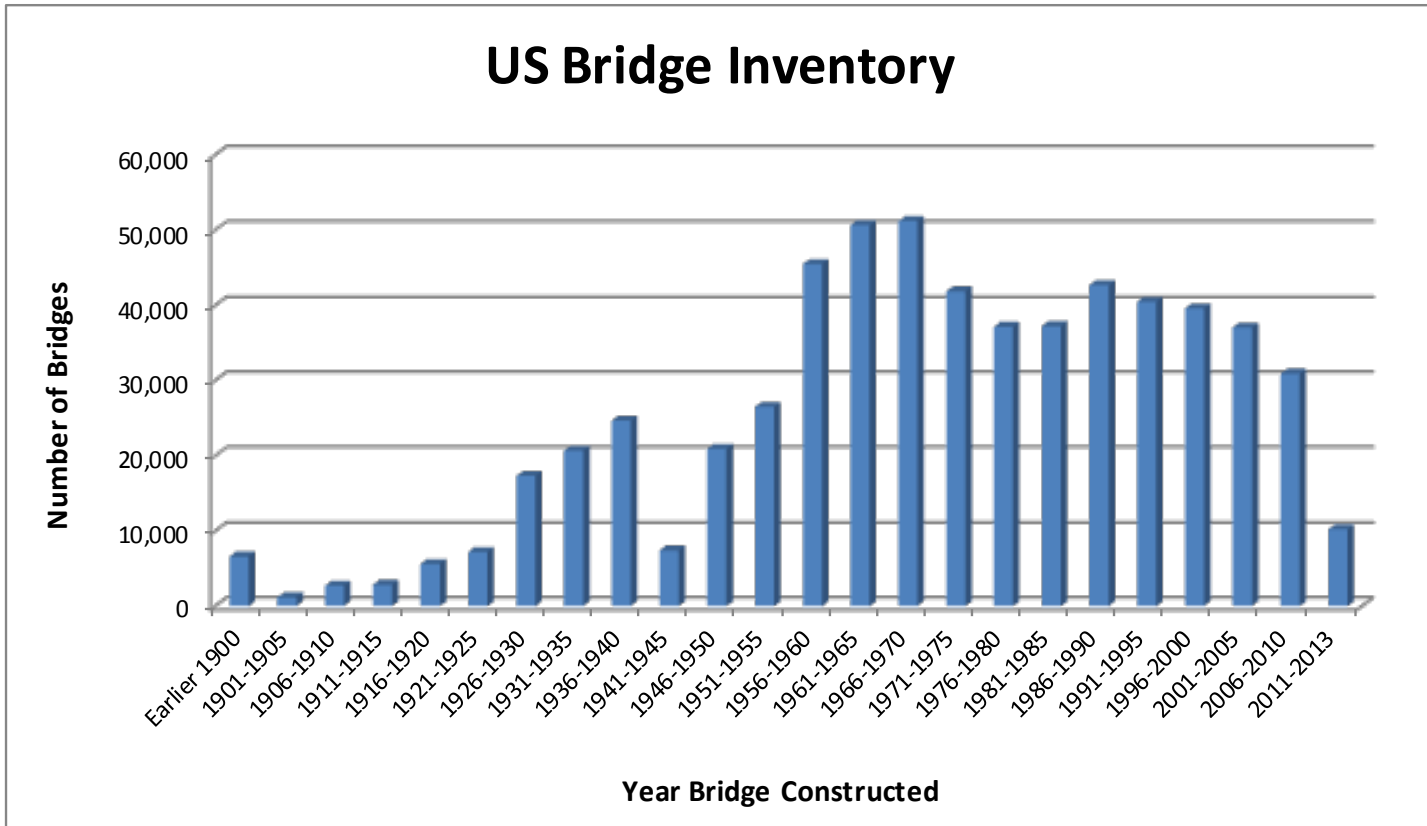
INTRODUCTION

Lack of proper maintenance operations is one of the main reasons for bridge deterioration.

According to AASHTO (2007) the most common problems affecting bridge structures includes:

- Corrosion of the reinforced steel in concrete decks due to the penetration of chloride ions from deicing products
- Leakage through damaged joints
- Malfunction of frozen bearings
- Pronounced bumps at bridge approach slabs
- Damaged coating systems.

BRIDGE PRESERVATION TREATMENTS AND BEST PRACTICES



USA: 607,751 bridges (Dec. 2013)
50% (NBI) exceeded a 50 years' service life
25% structurally deficient or functionally obsolete.

Indiana: 10% structurally deficient , 12% functionally obsolete

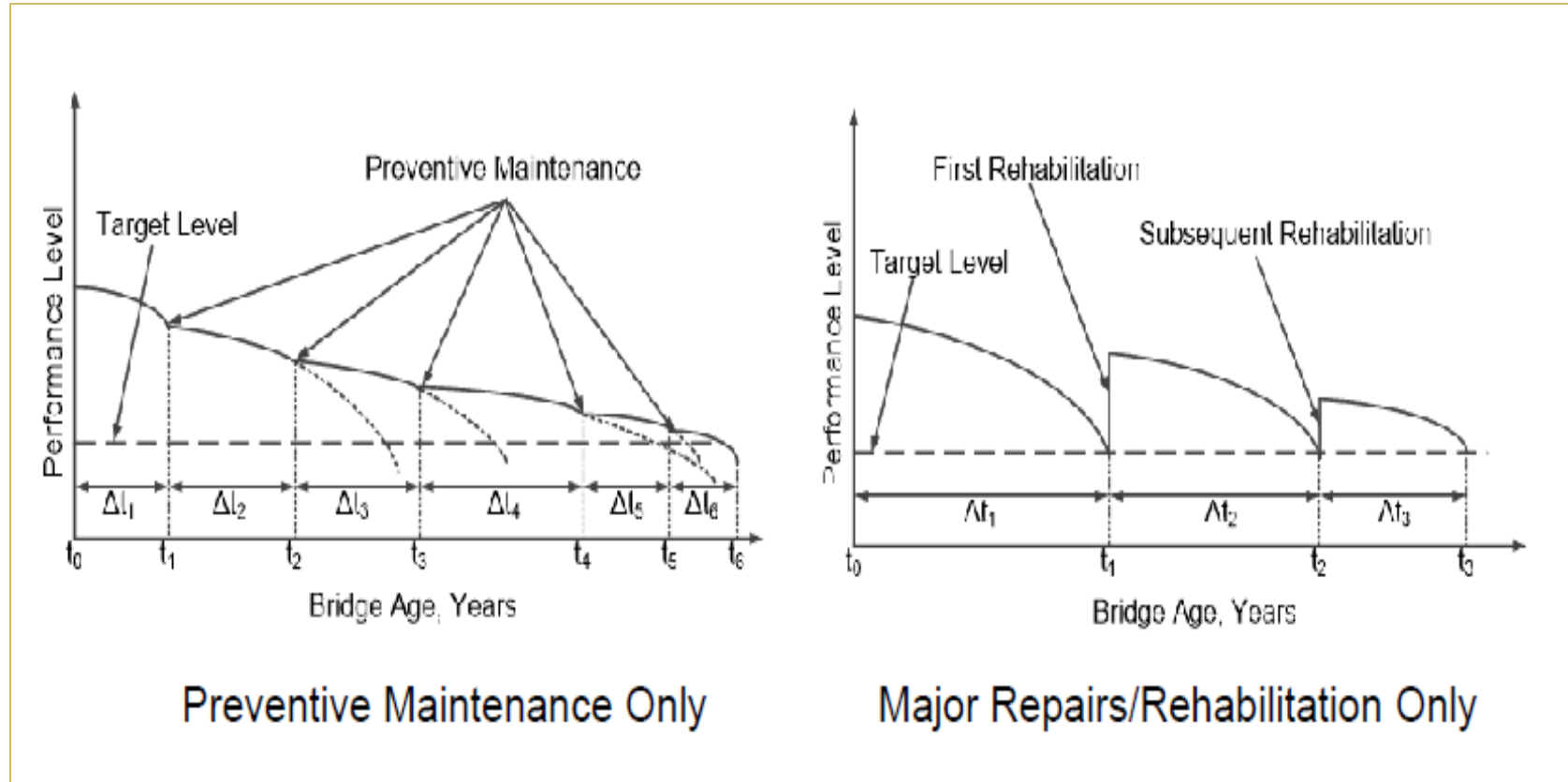
BRIDGE PRESERVATION TREATMENTS AND BEST PRACTICES

Department of Transportation agencies have to deal with increasing bridge preservation and replacement needs, often under a constrained budget.

A normal practice for DOT's is to be more reactionary when attending bridges' problems, mainly due to its "initial" low cost.

Regular preventive maintenance is the most efficient way to preserve and extend the bridges' service life.

BRIDGE PRESERVATION TREATMENTS AND BEST PRACTICES



Application of two maintenance programs. (Dunne, 2014).

“Preventive maintenance cannot be expected to extend the life or improve the service of a pavement or bridge that was poorly constructed or that has already deteriorated”

MnDOT

BASIC SUPPOSITION

Bridge preventive maintenance activities can prolong the life of Indiana bridges by consistently using simple, economical treatments at strategic points in a structure's life cycle.

OBJECTIVE AND SCOPE

Review bridge maintenance activities recommended by specialized literature, currently conducted by INDOT districts, and several DOT's agencies.

A list of new and enhanced bridge preventive maintenance activities will be proposed to INDOT.

The required conditions and frequency to perform each activity are analyzed.

The cost and benefit of each operation are studied.

These objectives were accomplished by completing the following tasks:

1. An extensive review of specialized literature on bridge maintenance.
2. Review of websites from selected DOT agencies.
3. Develop an initial list of bridge preventive maintenance activities.
4. Identification of most common bridge maintenance activities performed by selected DOT agencies (survey).

BRIDGE PRESERVATION TREATMENTS AND BEST PRACTICES

5. Identification of bridge maintenance activities performed by INDOT Districts personnel (interviews).
6. Refine list of selected preventive maintenance activities to be recommended for implementation by INDOT.
7. Economic evaluation of each maintenance activity.
8. Develop guidelines for best practices on the recommended preventive maintenance activities.

Literature Review

Extensive literature review to previous research by:

- FHWA
- AASHTO
- USDOT
- NCHRP
- State DOTs
- Other federal and state organizations
- Private institutions.

Additional research from:

- Reports
- Papers
- Conference presentations
- Dissertations

Review of Websites for Selected DOT's

States surrounding Indiana:

- Michigan
- Ohio
- Kentucky
- Illinois

States recommended by the INDOT Study Advisory Committee:

- Minnesota
- Louisiana
- New York
- Missouri

Preliminary List of Bridge Preventive Maintenance Activities

No.	MAINTENANCE ACTIVITY
1	Superstructure washing
2	Deck sweeping
3	Deck flushing/washing
4	Substructure washing
5	Vegetation control
6	Bearing lubrication
7	Pin & hanger lubrication
8	Drainage system cleaning / repair
9	Spot painting
10	Joint repair
11	Concrete sealing (deck &/or railing)
12	Minor concrete patching and repair
13	Concrete crack sealing
14	Approach pavement relief joints
15	Clean debris from bridge seats
16	Clean expansion joint seals
17	Clean debris and trees around piers

DOT Agencies Survey

- Michigan DOT – regular bridge maintenance program
- New York State DOT – regular bridge maintenance program
- Illinois DOT – bridge maintenance activities as reactionary
- Minnesota DOT – incremented bridge inspection and maintenance activities since the tragedy of August 2007
- Missouri DOT – very basic bridge maintenance activities

INDOT Districts Interviews

INDOT Districts perform very basic maintenance activities:

- Sweeping and deck washing regularly every year
- Wash the drainage system and clean joints

Most maintenance activities are performed as reactionary

- repair expansion joints
- deck patching
- deck crack sealing

Some activities are not performed by Districts due to the lack of adequate equipment.

Consolidated List of Bridge Preventive Maintenance Activities

No.	Maintenance Activity
01	Deck cleaning
02	Concrete deck maintenance
03	Deck joints cleaning/washing
04	Bearings/seats
05	Approach slab
06	Superstructure washing
07	Spot painting
08	Vegetation control
09	Removing debris from piers/abutments
10	Pin and hanger connection

Life Cycle Cost Analysis

The cost of keeping a bridge in safe and good condition is not a one-time expenditure based on the initial cost of construction, but a long-term investment during the whole expected service life.

Life Cycle Cost Analysis (LCCA) is a decision making tool oriented to show the benefits from different alternatives to achieve the same expected service life.

Life Cycle Cost Analysis

Cash flows from past, present or future actions have to be evaluated and compared.

A widely accepted method is evaluating the present value (PV), the value of any cash flow expressed as a value corresponding to the present time.

One-time future event:

$$PV = \frac{FV_n}{(1 + r)^n}$$

Equal annual events:

$$PV = \frac{C \cdot [1 - (1 + r)^{-n}]}{r}$$

Develop Guidelines

Guidelines prepared for the recommended bridge preventive maintenance activities.

Guidelines provide recommended procedures for INDOT bridge maintenance crews.

EXAMPLE OF TYPICAL MAINTENANCE ACTIVITY ANALYSIS

No.	Maintenance Activity
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CONCRETE DECK MAINTENANCE



CONCRETE DECK MAINTENANCE

Many snow belt states use deicing products to reduce snow accumulation over the decks during winter seasons

Due to salt use, bridge decks in Indiana and other states exhibit signs of deterioration in the concrete deck surfaces:

- Cracking
- Spalling
- Delamination

CONCRETE DECK MAINTENANCE

Several studies concluded that accelerated corrosion of reinforcing steel bars was the main cause, produced by the introduction of chloride ions from deicing products into the deck through the cracks

CONCRETE DECK MAINTENANCE

“The benefits of deicing salt are too great for its use to be discontinued, or even decreased, even though the cost of maintaining bridge decks is very high, so reducing the ingress of chlorides ions with methods of effectively and economically protecting concrete deck, have received special attention since the early 1970s.”

Virmani and Clemena, 1998

CONCRETE DECK MAINTENANCE

Includes the following activities:

1. Concrete deck sealing
2. Concrete deck crack sealing
3. Concrete deck partial patching

CONCRETE DECK MAINTENANCE

1. Concrete deck sealing



CONCRETE DECK MAINTENANCE

1. Concrete deck sealing

Deck sealing is applied to avoid the penetration of chloride ions from deicing products into the deck.

Sealers are classified into two main groups:

- Penetrating sealers
- Surface coatings

Penetrating sealers penetrates deeper into the concrete deck.

- Hydrophobic sealers (or water-repellants)
- Pore blockers.

CONCRETE DECK MAINTENANCE

1. Concrete deck sealing

Penetrating sealers have to be applied early after deck construction (approx. 3 to 6 months) and before the deck is contaminated by chloride ions.

Reapplication program of the sealer is necessary under a periodic basis.

CONCRETE DECK MAINTENANCE

1. Concrete deck sealing

Researchers	Service Life for penetrating sealer (years)
Weyers et al., (1993) - SHRP	5 to 7
Sherman et al., (1993) – Texas DOT	5
Zemajtis and Weyers, – Virginia Tech. (1996)	7
NYSDOT (1997)	4
Meggers (1998) – Kansas DOT	8 to 11
Soriano (2002) – South Dakota DOT	4 – 10
Sohanghpurwala (2006) – NCHRP Report 558	5 to 7
Mamaghani (2007) – North Dakota DOT	5
Wenzlic (2007) – Missouri DOT	3 to 10
Filice and Wong (2008) – Alberta DOT	4
Krauss et al., (2009) – NCHRP Project 20-07	5 to 10
Morse (2009) – Illinois DOT	4 to 5

CONCRETE DECK MAINTENANCE

2. Concrete deck crack sealing



CONCRETE DECK MAINTENANCE

2. Concrete deck crack sealing

Cracks became a direct path for the penetration of chloride ions into the concrete

Solution for crack sealing could be:

- penetrating sealers
- HMWM (high molecular weight methacrylate)
- epoxy injection

CONCRETE DECK MAINTENANCE

2. Concrete deck crack sealing

A good practice is reapply crack sealers in a cyclic scheme

- Wisconsin reseals cracks every 4 years
- Montana reseals every 15 years

Avoid unfavorable chemical reactions between deck sealer and crack sealer (Frosch et al., JTRP study).

CONCRETE DECK MAINTENANCE

3. Concrete deck partial patching



CONCRETE DECK MAINTENANCE

3. Concrete deck partial patching

Deck patching should be considered a temporary solution

The corrosion process is not totally stopped but delayed.

The new uncontaminated concrete in contact with old contaminated concrete generates a new corrosion activity in the area.

Some repaired decks showed significant corrosion problems after 7 years of reparation.

CONCRETE DECK MAINTENANCE

Life Cycle Cost Analysis

An economical analysis based on the Present Value (PV) for 4 alternatives:

- do not perform maintenance (Alternative 1)
- perform concrete deck maintenance – (Alternatives 2 to 4)

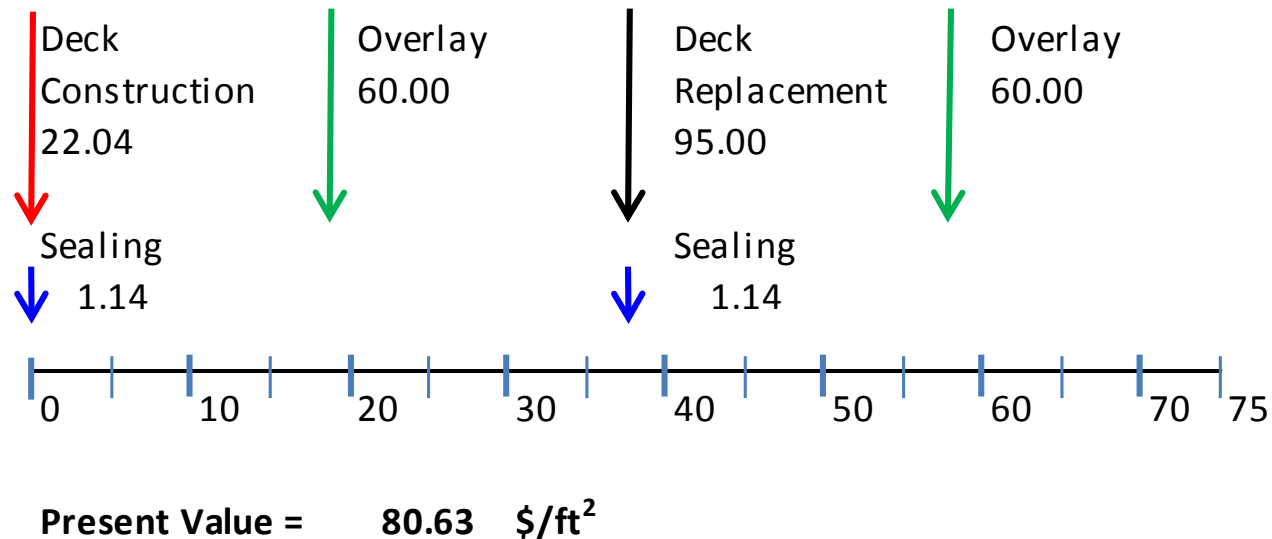
CONCRETE DECK MAINTENANCE

ALTERNATIVE 1:

No Maintenance: Current INDOT Policy

- Deck overlay at years 18.75 and 56.25
- Deck replacement at year 37.50
- Sealing new deck at year 0 and 37.50
- Bridge service life 75 years
- Discount rate of 4%

ACTIVITY	COST (\$/ft ²)
Deck Construction	22.04
Sealing	1.14
Overlay	60.00
Deck Replacement	95.00



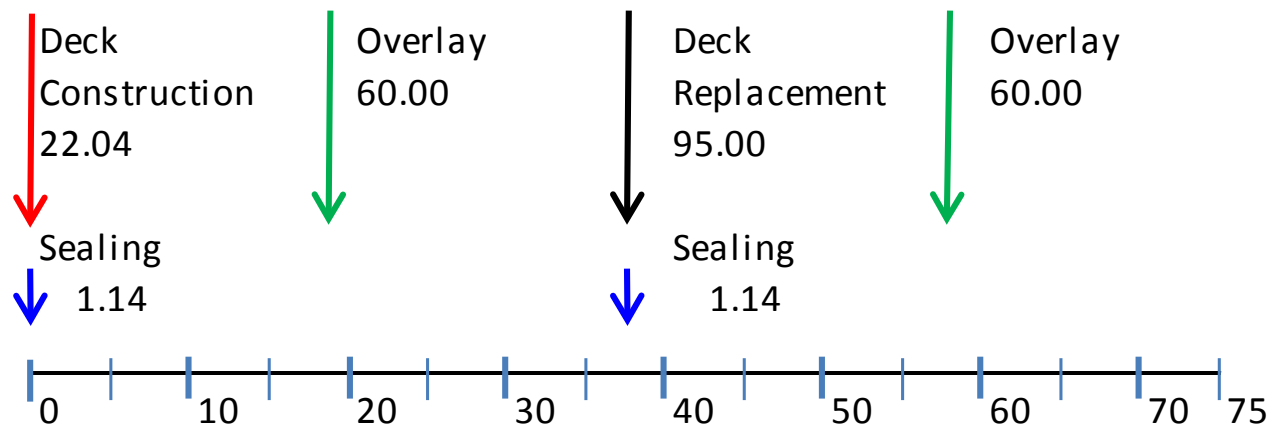
CONCRETE DECK MAINTENANCE

ALTERNATIVE 1:

$$PV = \frac{FV_n}{(1+r)^n}$$

$$PV = 22.04 + 1.14 + \frac{60.00}{(1.04)^{18.75}} + \frac{95.00}{(1.04)^{37.5}} + \frac{1.14}{(1.04)^{37.5}} + \frac{60.00}{(1.04)^{56.25}}$$

$$PV = 80.63 \text{ \$/ft}^2$$



Present Value = 80.63 \$/ft²

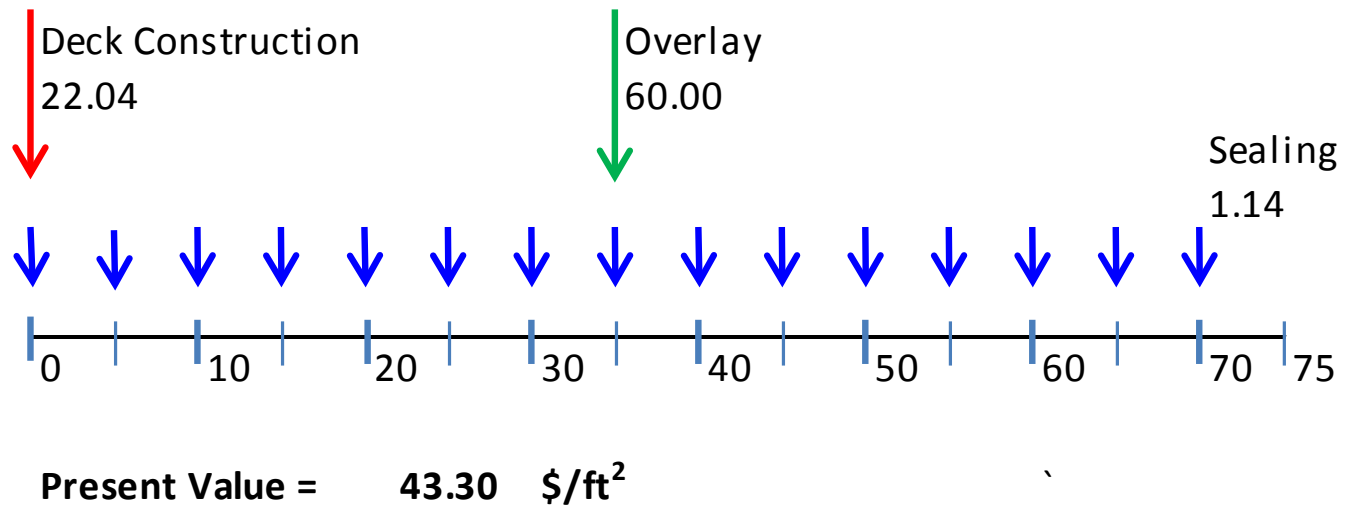
CONCRETE DECK MAINTENANCE

ALTERNATIVE 2:

Maintenance program

- Deck sealing each 5 years since year 0
- Deck overlay at year 35
- Bridge service life 75 years
- Discount rate of 4%

ACTIVITY	COST (\$/ft ²)
Deck Construction	22.04
Sealing	1.14
Overlay	60.00



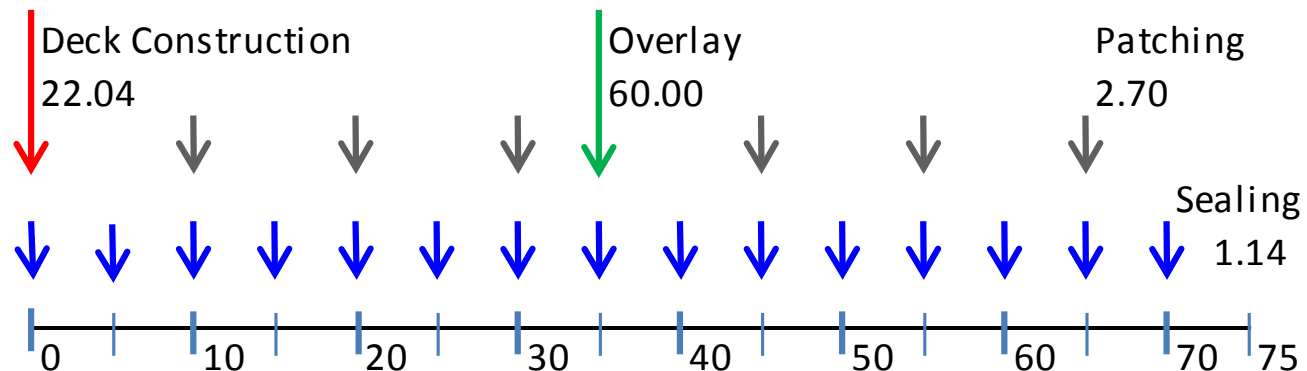
CONCRETE DECK MAINTENANCE

ALTERNATIVE 3:

Maintenance program

- Deck sealing each 5 years since year 0
- Partial deck patching each 10 years
- Patching 10% of total area =
 $\$27.03/\text{ft}^2 \times 0.10 = \$2.70/\text{ft}^2$
- Deck overlay at year 35
- Bridge service life 75 years
- Discount rate of 4%

ACTIVITY	COST (\$/ft ²)
Deck Construction	22.04
Sealing	1.14
Overlay	60.00
Partial deck patching	2.70



Present Value = 48.18 \$/ft²

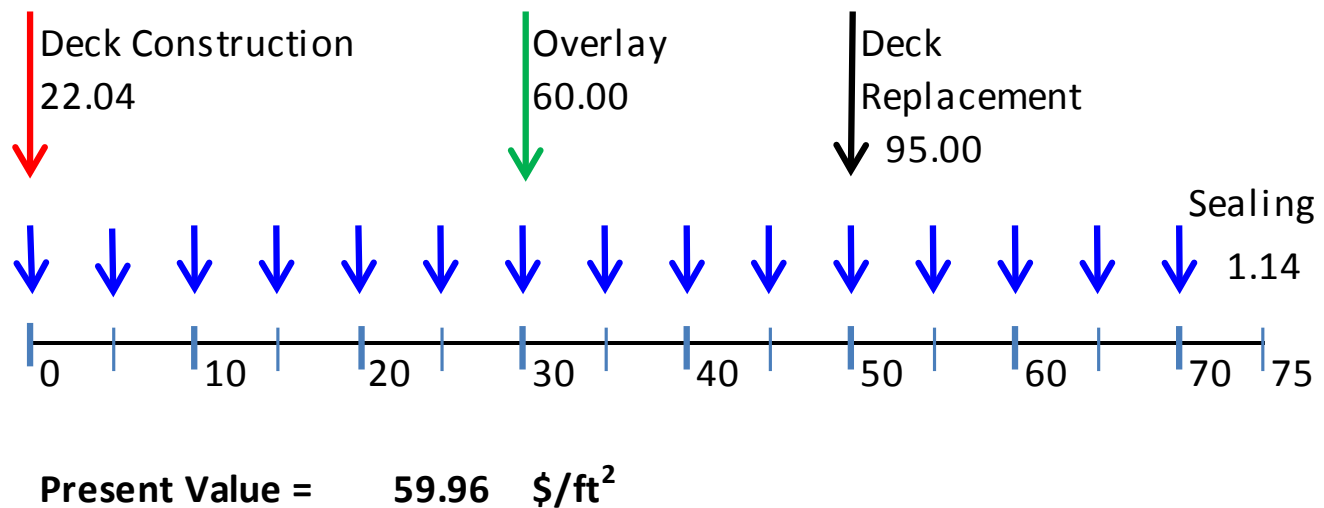
CONCRETE DECK MAINTENANCE

ALTERNATIVE 4:

Maintenance program

- Deck sealing each 5 years since year 0
- Deck overlay at year 30
- Deck replacement at year 50
- Bridge service life 75 years
- Discount rate of 4%

ACTIVITY	COST (\$/ft ²)
Deck Construction	22.04
Sealing	1.14
Overlay	60.00
Deck Replacement	95.00



CONCRETE DECK MAINTENANCE

ALT.	DESCRIPTION	Present Value (\$/ft ²)
1	No Maintenance: Current INDOT Policy	80.63
2	Sealing @ 5 years / Overlay at year 35	43.30
3	Sealing @ 5 years / Patching @ 10 years / Overlay at year 35	48.18
4	Sealing @ 5 years / Overlay at year 35 / Replace deck at year 50	59.96

CONCRETE DECK MAINTENANCE

Observations/Recommendations

It is always more cost-effective to perform a concrete deck maintenance program that includes:

- Seal all deck cracks
- Partial deck patching
- Seal deck with a penetrating sealant after 3 to 6 months of construction
- Repeat the maintenance program every 5 years

RECOMMENDED BRIDGE PREVENTIVE MAINTENANCE ACTIVITIES

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No.	Maintenance Activity
01	Deck cleaning
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10	Pin and hanger connection

BRIDGE PRESERVATION TREATMENTS AND BEST PRACTICES

1. DECK SWEEPING/CLEANING



1. DECK SWEEPING/CLEANING

- Deck flushing must be conducted very often to reduce chloride penetration.
- Consider deck flushing before sealer application
- Deck flushing not necessary otherwise.

1. DECK SWEEPING/CLEANING

- Perform deck sweeping every year, preferably after the end of the winter season.
- Perform cleaning/washing the bridge drainage system every year.

2. CONCRETE DECK MAINTENANCE



2. CONCRETE DECK MAINTENANCE

- Seal the concrete deck with a penetrating, silane-based, hydrophobic, sealer.
- Seal the deck early after the construction of the deck, approximately after 3 to 6 months.
- Repeat the sealing at 5 year intervals.
- Seal concrete deck cracks when is required using high molecular weight methacrylate (HMWM) or epoxy crack sealer based on the characteristics of the cracks.

2. CONCRETE DECK MAINTENANCE

- Partial patching to “small” potholes previous to deck sealing.
- Seal the deck after all cracks have been sealed appropriately.
 - ❖ “small” potholes are considered when the deck reinforced bars have not been compromised by corrosion due to chloride ions penetration.

3. DECK JOINTS CLEANING/WASHING



3. DECK JOINTS CLEANING/WASHING

- Clean and flush deck joints every year
- Seal minor problems on seals every year
- Replace joints every 10 years.

4. BEARINGS CLEANING/LUBRICATING/PAINTING



4. BEARINGS CLEANING/LUBRICATING/PAINTING

- Clean and wash elastomeric and steel bearings and seats each 2 years
- Lubricate steel bearings each 4 years.
- Spot paint steel bearings each 10 years.

5. APPROACH SLAB MAINTENANCE



5. APPROACH SLAB MAINTENANCE

- Seal the approach slab with a penetrating sealant after 3 to 6 months of slab construction.
- Seal all slab cracks with HMWM or epoxy.
- Repeat the slab and cracks sealing every 5 years.
- Clean and flush the approach slab joints every year and replace them every 10 years.
- Clean and flush the approach slab drainage systems every year.

6. SUPERSTRUCTURE CLEANING/WASHING



6. SUPERSTRUCTURE CLEANING/WASHING

- Clean and wash steel superstructure each 2 years
- Perform this activity after the end of the winter season
- Verify there is low contaminant when discharging to stream under the bridge

7. SPOT PAINTING



7. SPOT PAINTING

- Apply spot painting each 10 years.
- Verify there is not lead paint.
- Apply spot painting when no more than 10% of total area is the problem.

8. VEGETATION CONTROL



8. VEGETATION CONTROL

- Provide vegetation control every year.
- Eliminate all brush, tree branches, and tree limbs that can:
 - obstruct visibility to drivers
 - obstruct traffic signals
 - damage any bridge sub/superstructure element
 - obstruct or damage the drainage system
 - become a traffic hazard

9. REMOVING DEBRIS FROM PIERS/ABUTMENTS



9. REMOVING DEBRIS FROM PIERS/ABUTMENTS

- Perform debris removal every year.
- Implement routine inspections on the most important bridges after each flooding.

10. PIN AND HANGER CONNECTION



10. PIN AND HANGER CONNECTION

- Clean and flush the pin and hanger members every two years.
- Clean and flush the expansion joints located over the pin and hanger connections every year.
- Lubricate the contact surfaces between members in the pin and hanger connection every 4 years.
- Spot paint the elements each 10 years.

SUMMARY

- Ten maintenance activities developed based on standard practice.
- Economic analysis conducted to determine viability of each maintenance activity.
- Regularly perform all ten activities at recommended frequency.
- Guidelines provided for all maintenance activities.

QUESTIONS?